1up.

DIVISION OF THE PACIFIC OCEAN BASED ON TRANSPARENCY

E. N. Khalemskiy and V. I. Voytov

Translation of: "Rayonirovaniye vod tikhogo okeana po prozrachnosti."
In: Optika okeana i atmosfery (Optics of the Ocean and The Atmosphere), Edited by K. S. Shifrin, Leningrad, "Nauka" Press, 1972, pp 181-187

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, DC 20546 SEPTEMBER 1973

DIVISION OF THE PACIFIC OCEAN BASED ON TRANSPARENCY

E. N. Khalemskiy and V. I. Voytov

When the mass of geophysical data are generalized, the necessity inevitably arises of grouping them objectively in terms of stable indices which reflect the specific nature of the values being studied, since these values depend on the factors in the environment which determine them. This pertains to the optical characteristics of the Pacific Ocean, primarily to the physical transparency of the water, about which a great deal of data has recently been compiled. /181*

The optical structure of the water in the Pacific Ocean is formed as a result of the simultaneous action, on the one hand, of dynamic processes (flow, turbulence, and processes in the convergence zones) and, on the other hand — biological and geological processes which influence the formation and inflow of particles having an organic and inorganic origin. The action of these processes increases the field gradients of the suspended matter and the field gradients of the optical characteristics, whereas the role of advection and turbulent diffusion is manifested in the equalization of the concentration of suspended matter and, consequently, the smoothing of the optical field gradients.

---

*Numbers in the margin indicate the pagination of the original foreign text.

The interaction of geophysical and biological factors in each specific region of the ocean leads to the formation of an optical structure of the water which is typical for the given season, and produces a definite picture of the distribution of optical properties.

In actuality, as is shown by an analysis of the three-dimensional distribution of values of the attenuation coefficient ε (or the physical transparency θ), which is the most important of the hydrotopic characteristics, the values of ε for λ = 546 nm in winter in the northern hemisphere are grouped in such a way that there are expansive water areas in which these values fluctuate within comparatively small limits. This may be clearly seen in Figure 1, which gives a graph showing the reproducibility of the values for the attenuation coefficient, compiled with allowance for all values of ε which we shall assume for the surface waters of the Pacific Ocean. The values of ε are plotted on the abscissa, and the number of points N on the surface of the ocean, in which the measurements were performed, is plotted on the ordinate. /182

Based on the form and nature of the graph, we may distinguish four arbitrary types of ocean water, which differ in terms of transparency: maximum, high, normal, and reduced. We should note that we could even speak of waters with low transparency. However, they are not characteristic for the open ocean, and are only encountered in a very narrow zone along the shore. Therefore, we shall not discuss this type of water.

The map (Figure 2) shows the distribution of these types of water in the Pacific Ocean. When comparing this map with similar maps of plankton, suspended matter, primary products, and also a scheme for the surface circulation of water in the Pacific

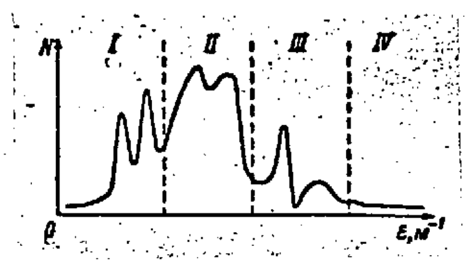

Figure 1. Reproducibility of attenuation coefficient for light ε in surface waters of the Pacific Ocean.

Transparency of the water: I — maximum; II — high; III — normal; IV — reduced.

Ocean [1 — 4], we may observe a definite similarity in the spatial distribution of all these elements.

On a very large scale, this similarity consists of the presence of latitudinal and circumcontinental zonality in the distribution of these elements, including transparency.

The circumcontinental zonality is apparent in the regular change in transparency with increasing distance from the shore. Two zones of water may be observed — coastal water and water in the open ocean. In the Pacific Ocean, the coastal zone with waters of reduced transparency has the form of a very narrow band, which is natural, since no large rivers enter into the Pacific Ocean, there are no extensive regions of eolian suspended matter, and rocky coasts predominate, i.e., there are no power- /183
ful sources of suspended matter from the continents.

In the open ocean, the transparency distribution is characterized by a latitudinal zonality, which is related to the latitudinal structure of the horizontal circulation of water in the Pacific Ocean.

An important feature of the macro-scale distribution of transparency in the surface waters of the Pacific Ocean is the coincidence of areas of separate types of water (in terms of transparency) and the location of the main ocean currents. Thus, /184
regions of water having the maximum transparency are "superimposed" on subtropical convergences of the northern and

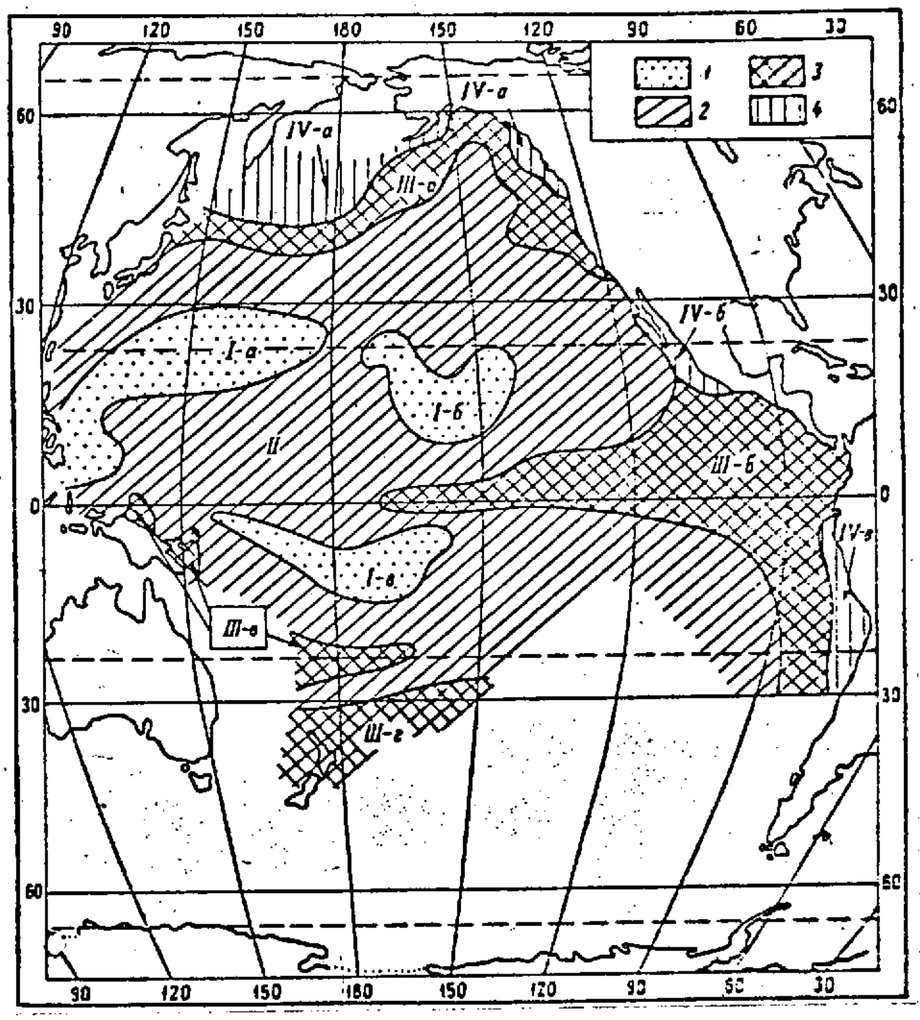

Figure 2. Hydrotopic division of water in the Pacific Ocean based on transparency.

Transparency of the water: 1 — maximum (first type); 2 — high (second type); 3 — normal (third type); 4 — reduced (fourth type). The Roman numerals are the hydrotopic regions (see Table 1).

southern hemispheres. At the same time, the regions occupied by the main currents, which comprise the tropical and subtropical cycles, primarily contain water of high transparency, which is encountered in a large portion of the Pacific Ocean, so that their transparency may be assumed to be most characteristic for water in the ocean as a whole (for winter in the northern hemisphere). This is confirmed by the graph in Figure 1, from which it may be seen that the greatest amount of data pertain to these waters, in spite of their uniform distribution throughout the ocean.

The portion of the Pacific Ocean, which is filled with water of the remaining two types of transparency, consists of individual regions, having features such as latitudinal and circumcontinental zonality. It is interesting that the regions of water with reduced transparency differ, depending on the source of the suspended matter. Thus, these waters are observed at the Equator and close to the Peru and California coasts, i.e., zones with intense upflow of waters from the depths which are rich in biogenic elements and therefore have a high yield of plankton. The terrigenous sources of suspended matter, which are completely different, are "fed" by water of reduced transparency along the Canadian coast, which has a great many cliffs, and in the zone of the Aleutian and Kurile peninsulas, where the water is in violent motion in the straits, which encompasses the entire depth of the water, and due to this the water is rich in mineral matter.

Thus, the ocean region, which is filled with waters of one type of transparency, can hardly be regarded as a region which is homogeneous in the optical sense, since a different combination of dynamic elements and sources of suspended matter (i.e., the basic factors which form the field of optical properties in the ocean) may exist in different parts of it. However, it is known that the stable combination of these factors tends to produce a stable optical structure of the water, having a certain

TABLE 1

Index of the region (Fig.2)	Name of region
Ia	western part of the subtropical convergence of the northern hemisphere
Ib	eastern part of the subtropical convergence of the northern hemisphere
Ic	subtropical convergence of the southern hemisphere
IIIa	transitional zone between subpolar and subtropical waters of the northern hemisphere
IIIb	equatorial-tropical region of the eastern hemisphere
IIIc	southwestern region of island waters
IIId	region of temperate waters in the southern hemisphere
IVa	subpolar region of the northern hemisphere
IVb	region of the California current
IVc	region of the Peru current

homogeneity of the optical properties.

Therefore, it is natural to try and subdivide the regions considered, which are filled with waters of a single type of transparency, into regions which have a definite combination of these factors. The distribution of these regions, which we distinguished in the Pacific Ocean, is shown in Figure 2, and their names are given in Table 1.

It is apparent that in these regions, which may be arbitrarily called quasi-homogeneous hydrooptical regions, the variability of the optical properties must be less than in the entire region as a whole. The validity of distinguishing between hydrooptical regions may be objectively analyzed by comparing and analyzing the statistical parameters of the optical fields, calculated for /185 regions of each type as a whole and for individual hydrooptical regions.

For this purpose, we obtained the values of the average transparency $\bar{\theta}(\lambda = 546\ nm)$ and the mean square deviation σ_θ for each region as a whole and for separate regions. The relationships between these parameters, as well as the values of the variation coefficient $\sigma_\theta/\bar{\theta}$, are given in Table 2.

For analyzing the data in the table, we must first note the overall increase in the variation coefficient from the more transparent waters to the less transparent waters. This points to an increase in the nonuniformity of the transparency field in the more turbid waters. It may be assumed that this is caused by the increased role of the cloud-like distribution of suspended matter in the more turbid waters, which is manifested in an increase in the transparency gradients.

Interesting conclusions are obtained when comparing the data for all regions with water of a given type and the values pertaining to individual regions within it. When the value of $\bar{\theta}$ does not change in practice (Table 2, column 6), there are great fluctuations in the value of σ_θ (column 7) and the variation coefficient. The changes in the variation coefficient are particularly important, since this makes it possible to estimate the nonuniformity of the transparency field of individual regions with respect to the optical types as a whole.

In the majority of cases (4 out of 6), the dispersion of transparency and the transparency variation coefficient for the regions are equal to, or much less than, the corresponding values /186 for the type as a whole. Thus, the purpose of the classification

TABLE 2

Optical type of water or region	No. of stations	Ratio of the given type to the first type		Ratio of the region to the type as a whole		Variation coefficient
		$\frac{\bar{\theta}\text{ type}}{\bar{\theta}^1\text{ type}}$	$\frac{\sigma_\theta\text{ type}}{\sigma_\theta{}^1}$	$\frac{\bar{\theta}\text{ reg.}}{\bar{\theta}\text{ type}}$	$\frac{\sigma_\theta\text{ reg.}}{\sigma_\theta\text{ type}}$	$\frac{\sigma_\theta}{\bar{\theta}}$
	3	4	5	6	7	8
First type	58	1.00	1.00	—	—	0.034
Region Ia	35	—	—	1.01	1.00	0.034
Region Ib	11	—	—	0.99	0.69	0.024
Region Ic	12	—	—	1.00	1.24	0.042
Second type	150	0.90	1.38	—	—	0.052
Third type	35	0.75	1.00	—	—	0.056
Region IIIa	14	—	—	1.03	0.90	0.039
Region IIIb	11	—	—	1.01	1.34	0.060
Region IIIc	7	—	—	1.00	0.72	0.033
Fourth type	7	0.54	2.28	—	—	0.143

has been achieved, which is to distinguish, in regions containing water of a definite optical type, the water regions with a more uniform transparency field.

However, for two regions (Ic and IIIb) the dispersion and the transparency variation coefficients significantly exceed the similar values for this type, i.e., the optical inhomogeneity of the transparency field for these regions is greater than the average inhomogeneity of the field in the entire region of water of the given type. In region Ic, which contains an area of subtropical convergence of the southern hemisphere, this is due to the fact that the boundary of the first type of region is not drawn accurately enough and other areas containing water of different optical types are included.

In actuality, in the western part of this region (to the west of 180°) the subtropical convergence is difficult to follow, due to which a complex dynamic system with currents from different directions is observed. This causes this region, which contains water of the first type, to also contain relatively more turbid waters pertaining to the second type, and even to the third optical type on the extreme western part of the region (enriched with suspended matter from water in the insular zone). Under these conditions, it is very difficult to draw an accurate boundary for the region, and a large amount of data are necessary, which we presently do not have.

The situation is somewhat different in region IIIb, which /187
is located in the equatorial-tropical region of the eastern hemisphere. Here the increase in the dispersion and the transparency variation coefficient points to the necessity of dividing the area into several regions which are smaller in terms of magnitude and more homogeneous in the optical sense. An analysis of the dynamic processes and the nature of the suspended matter sources shows that such a finer division is possible. The small number of existing transparency measurements is the only obstacle to a more exact classification of the optical regions in this area of the ocean.

As a whole, the data shown in Table 2 indicate the correctness of this method of hydrooptical division of the Pacific Ocean based on transparency, which can be used in its present form to solve differing problems, as we have already done. The increase in the volume of measurement data and the amount of optical characteristics directly determined in the sea can supplement this classification system, so that it may satisfy both scientific requirements and the constantly increasing problems of the practical conquest of the ocean.

REFERENCES

1. Bogdanov, Yu. A. Formirovaniye i raspredeleniye biogennogo osadochnogo materiala v Tikhom okeane (Developing and Distributing Biogenic Sedimentary Material in the Pacific Ocean). Candidate's Dissertation, 1965. Arkhiv IOAN SSSR (Archives of the USSR Institute of Oceanology of the Academy of Sciences).

2. Gidrologiya Tikhogo okeana. Tikhiy okean (Hydrology of the Peacific Ocean. Pacific Ocean). Vol. 2, Moscow, Nauka Press, 1968.

3. Koblents-Mishke, O. I. Primary Production of the Pacific Ocean. Okeanologiya, Moscow, Vol. 5, No. 2, 1966.

4. Semina, G. I. Phytoplankton of the Pacific Ocean. In the book: Biologiya Tikhogo okeana (Biology of the Pacific Ocean), Book 1, Plankton, Moscow, Nauka Press, 1967.

Translated for Goddard Space Flight Center under contract No. 2483 by SCITRAN, P. O. Box 5456, Santa Barbara, California, 93108.

STANDARD TITLE PAGE

1. Report No. NASA TT F-14,784	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle DIVISION OF THE PACIFIC OCEAN BASED ON TRANSPARENCY		5. Report Date September, 1973
		6. Performing Organization Code
7. Author(s) E. N. Khalemskiy and V. I. Voytov		8. Performing Organization Report No.
		10. Work Unit No.
9. Performing Organization Name and Address SCITRAN, P. O. Box 5456 Santa Barbara, California 93108		11. Contract or Grant No. NASW 2483
		13. Type of Report and Period Covered Translation
12. Sponsoring Agency Name and Address NASA, Washington, DC 20546		14. Sponsoring Agency Code

15. Supplementary Notes

Translation of: "Rayonirovaniye vod tikhogo okeana po prozrachnosti," Optika okeana i atmosfery, (Optics of the Ocean and the Atmosphere), Edited by K. S. Shifrin, Leningrad, "Nauka" Press, 1972, pp. 181-187

16. Abstract

The Pacific waters are classified, based on transparency, and hydrooptical regions in the Pacific are located and tested by means of statistical methods.

17. Key Words (Selected by Author(s))		18. Distribution Statement Unlimited - Unclassified	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 12	22. Price 4.00